TECHNOLOGY PERVASIVE ECO-MONITORING

Long heralded as **the next wave** in **computing**, pervasive computing is finally becoming a reality. Soon, it will be possible to instrument our world with sensors, actuators, and processors, and information processing will be integrated into nearly all objects and environments. Over the next decade, this technology may find its premiere application in helping us cope with environmental challenges—pervasive computing may become pervasive eco-monitoring. But the balance sheet for the planet may not be entirely favorable: the environmental costs of the technology could themselves outweigh the benefits.

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THE REALLY BIG PICTURE:
MAKING THE VISIBLE INVISIBLE

Pervasive computing promises a lightweight approach to building a sustainability infrastructure—a pervasive eco-monitoring network that shows what's really happening in large complex ecological systems, in real time. Indeed, pervasive computing could make detailed information about resource and energy usage visible, from the scale of households to cities and even continents. It could proactively guide more efficient uses of those resources and provide both officials and individuals with information about local pollution, energy waste, or health threats. Most importantly, these systems will deliver immediate feedback about the short- and long-term consequences of actions taken in the present.

Massively large-scale environmental sensing projects are already underway. The National Ecological Observatory Network (NEON) is laying the groundwork for distributed sensor monitoring of ecological systems at the continental scale. MIT's Media Lab is pursuing "wikicity" projects that combine data feeds from local utilities and services to provide real-time maps of major metropolitan areas. Meanwhile, tools like Australia's CSIRO Catchment Modeling Toolkit provide open- source modules for modeling the use of water. Such tools also be critical not only in policy, but also in the development of economic innovations tied to sustainability: "triple bottom line" accounting, the creation of carbon trading markets, and the cost/benefit assessment of new environmental service programs.

THE VIEW FROM THE GROUND:
CITIZEN MONITORS

Pervasive eco-monitoring is not all top down, however. From mobile phones with pollution monitors to visualizations of environmental sensor data, pervasive computing promises to engage the public in a more personal bottom-up environmental science. Mobile sensors could help citizens measure directly how urban pollution impacts key personal health measures in real time—as well as documenting patterns of urban health. Instrumented trashcans could yield household insights into a family's role in the ecological lifecycle of products—and profile waste patterns at the neighborhood, city, or even regional level. The challenge will come from reconciling these new "freedoms of environmental information" with the uses of that information. Who owns it? Who has access to it? And how does it feed policy, regulation, even law enforcement?

THE FINAL TALLY:
THE PARADOX OF SMALL

Pervasive computing works for eco-monitoring because it's small, distributed, and—well—pervasive. But therein lies a paradox: as small as networked sensors are, their own ecological footprint is potentially very large. The smaller a device, the more resources and energy are required in its manufacture. And pervasive computing requires lots and lots of these devices. Their waste is rife with lead, mercury, and other toxins, while their rapid obsolescence wreaks havoc on the landfill.

Fortunately, the computer industry has stepped up its commitment to green manufacturing and recycling. At the same time, new technologies promise more closed-loop components, for example, eliminating the need for batteries in small devices by scavenging power through photovoltaics or even the kinetic motion of the devices themselves. The key will be to ensure that the paradox of the small does not become a big barrier to pervasive computing's potential but rather an opportunity to further drive the greening of the tech industry.